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EXAMINING THE LONG TERM RELATIONSHIP BETWEEN CRUDE OIL AND FOOD COMMODITY PRICES: CO-INTEGRATION AND CAUSALITY

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ABSTRACT
Recently a new debate has started regarding food and energy issues because food has become an alternative source of energy and energy becoming the main input of agriculture. However, this study attempts to investigate the possible long-term relationship between the prices of crude oil and food commodities represented by maize, wheat, sorghum, soybean, barley, linseed oil, soybean oil, and palm oil. Time series econometric techniques (Unit root tests, Co-integration, and Granger causality) were applied. The study utilizes monthly data over the period of 1980 to 2009. The results of this study reveal that there is a strong evidence of long-term relationship between crude oil and the food commodities prices. A traditional Granger Causality is used to check whether causality exists between two product prices. The outcome suggests that there is unidirectional causality between the prices crude oil and some of the food commodities under examination.

Keywords: *Food commodities prices, Crude oil, Co-integration, Causality.*

1. INTRODUCTION

Recently a new debate has started regarding food and energy issues because food has become an alternative source of energy and energy is becoming the main input of agriculture. "The Food Versus Fuel Debate", was the title of the August 2009 issue of Journal of Agricultural and Applied Economics. Indeed, there is no day when daily financial newspapers do not dedicate many columns to commodity-related issues, from gold to wheat, rice and maize, while an unprecedented rise in oil prices has inflamed all markets *(Geman, 2005)*. This makes us wonder whether the prices of food commodities are affected by energy prices. Moreover, is there any relationship between both? Should the scarcity of resources such as energy begin to alarm us? Is there any linkage between bio-fuel production and high crude oil prices?

There is a growing concern in all nations about the long-term sustainability of the energy-intensive lifestyle that the industrialized world has developed, and moreover, whether the earth can ever support this level of development for the majority of the world's people. These concerns stem from the pressure of continuing growth in population and in energy use per capita on a planet that has finite resources and a finite capacity to assimilate wastes. The world population is now at 7 billion and is growing at a rate of 1.15 percent a year, adding around 77 million people to the earth annually, and it is now estimated that it will become 9 billion by 2042 *(World Population Clock, 2009)*. Modern life and population growth is accompanied by steady growth in food and energy demand. Total world consumption of marketed energy is projected to increase by 44 percent from 2006 to 2030 *(Energy Information Administration, 2009)*. In the same vein, global food demand will double by 2050 *(United Nations, 2009)*.

As we have noticed during the recent economic crisis, almost all the prices of hard and soft commodities have increased rapidly. The unprecedented increase in food commodity prices has led to the so-called 2008 food crisis. During the 2008 crisis many studies aimed to discover and explain the main reasons behind the unprecedented increase in prices for almost all food commodities *(Harrrison, 2009, Von Braun et al., 2008)*. Cereal prices increased 132 percent from January 2006 to March 2008 *(Arshad and Hameed, 2009)*. A combination of record low global inventory levels, weather-induced supply side shocks, surging outside investor influence, record oil prices and structural changes in demand for grains and oilseeds due to bio-fuels have resulted in high prices *(Banse, 2008)*. But did the high crude oil prices cause this bubble in prices for all food commodities, especially for those crops used in bio-fuel production?

On the other hand, various markets are currently more dependent than ever before on each other. The inter-relationship between markets has become an important subject to explore with the increased influence of globalization and international trade. One of those relationships is the one between crude oil and food commodities. The relationship between the prices of crude oil and food commodities has surfaced with the start of the recent food crisis. Added to this, the last two decades have experienced dramatic changes in world commodity markets. Political upheavals in some countries, economic mutation, new environmental regulations, a huge rise in the consumption of commodities in countries such as China and other structural changes have contributed to an increase in the volatility of supply and prices.

The overall objective of this study is to observe and explore how the prices of crude oil directly and indirectly affect the prices of cereals, and seeks to understand how biofuel production maximizes the effects of the crude oil prices.

However, this study attempts to answer these questions. The study examines how internationally-traded food crop prices have changed, and then delves into the reasons why this has occurred and looks at the medium-term price prospects. It also analyzes the extent of the relationship between the crude oil and cereal prices.

1.1 Study Hypothesis

H_0: Changes in the prices of petroleum cannot play an important role in changing cereal and other food commodity prices.
H_1: Changes in the prices of petroleum play an important role in changing cereal and other food commodity prices.

2. LITERATURE REVIEW

Existing literature on the effect of crude oil on agricultural commodities is new; almost all studies related to this topic began after the 2008 food crises. Even so, several books, magazines, and articles have highlighted the many underlying issues related to the topic such as the main reasons for unprecedented food prices, and the reasons for high energy prices. Some studies have examined the relationship and the long-run relationship among soft commodities prices and in some cases among selected soft commodities prices and crude oil price.

Campiche *et al.* (2007) analyzed the co-variability between crude oil prices and soybean, soybean oil, corn, sorghum, palm oil, and sugar prices from 2003 to 2007 using a vector error correction model. The focus of the study was to investigate the co-integration between the mentioned food products and crude oil. Their co-integration results indicate that soybean and corn prices were co-integrated with crude oil price during the 2006-2007 time frame but not during the 2003-2005 period. Other results from the same study indicate that crude oil prices do not adjust to changes in the corn and soybean market. The authors concluded from their analysis that soybean prices seemed to be more correlated to crude oil prices than corn prices. These results confirmed Arshad and Hameed's (2009) results. One limitation to this study was the limited number of commodities the authors used to examine the co-integration.

Arshad and Hameed (2009) addressed one specific question: is there a long-term relationship between petroleum or crude oil and cereal prices? They conducted unit root, co-integration, and Granger causality tests between petroleum and each of maize, rice, and wheat. It is hypothesized that the changes in petroleum prices play an important role in changing major cereal prices. The results in this study supported the hypothesis that there is evidence of a long-run equilibrium relationship between the two prices of the two products. These results suggest that the petroleum price factor is growing in significance in the cereal complex since modern agriculture depends heavily on the use of fossil fuel in every stage of food production and marketing. All of these results combined confirm the hypothesis that there is a relationship between crude oil prices and that of major cereals, and changes in petroleum prices play an important role in this game.

Yu *et al.* (2006) analyzed the co-integration and causality of higher crude oil prices on the price and demand for vegetable oils. They concluded that the influence of shocks in crude oil prices on the variation in vegetable oil prices is relatively small, which appears to reflect the results in Campiche (2007).

Fabiosa (2009) studied the impact of the crude oil prices on the livestock sector under a regime of integrated energy and grain markets. The author found that the correlation structure between crude oil and grain prices increased dramatically, becoming more statistically significant. According to the author, prior to the ethanol boom, the correlation between the crude oil prices and corn was -0.117 and this figure increased to 0.876 during the ethanol boom period, and as well for other grains.

Hameed and Arshad (2008) investigated the long-term relationship between the prices of crude oil and each of palm, soybean, sunflower and rapeseed oil prices. To achieve their goal they adopted a simple model to express the relationship between petroleum and each of the major vegetable oil prices to test the hypothesis of whether or not changes in petroleum prices play an important role in changing them. They applied the Engle-Granger two-stage estimation procedure using monthly data over the period of January 1983 through March 2008. The main focus was to confirm the hypothesis that a relationship between crude oil and vegetable oil existed. The results indicated that there is strong evidence of a long-run equilibrium relationship between the two product prices.

Abbot *et al.* (2008) looked into the relationship between rising crude oil prices and an increase in the United States current account deficit. According to the authors the steady increase in oil prices and the decrease in the value of the United States dollar resulted in higher corn prices in the United States as the decreased dollar resulted in cheaper corn exports in places like China and India.

3. METHODOLOGY

In order to account for structural changes in the production, demand and supply of crude oil, technological changes, and the industrialization of the food system, this study utilizes the methodology suggested by Engel and Granger (1987). This methodology is based on 10 time series, each series containing 12 x 30 (360) observations, therefore making 3600 observations in total.

All the prices of all the commodities under examination in this study are nominal and have been obtained from the International Financial Statistics (IFS) online service. The commodities under examination are as follow:

- Prices of wheat and maize refer to the FOB price in the Gulf of Mexico, while prices of rice and soybean oil refer to the FOB price in Bangkok and the USA respectively.
- Prices of soybean and palm oil refer to the CIF price in the USA, and Malaysia respectively.
- Prices of sorghum and linseed refer to prices in Canada, and the United States, respectively.
- Prices of crude oil refer to the average U.K. Brent, Dubai, and West Texas intermediate prices.

3.1 Data

The period chosen for this study extends from January 1980 to December 2009. The reason for selecting this period of time is because during this period, many important economic events have occurred: (1) it is a long enough period to be able to determine the nature of long run relationships between series; (2) the last few years have seen a phenomenal increase in primary commodity prices. According to the International Monetary Fund, the price index for all primary commodities increased 204% between January 2000 and March 2008. The major source of this increase is the rise in petroleum prices which registered an increase of more than 300% while food has increased by 107% during the same stated period; (3) rapid Chinese growth is the single most important economic phenomenon of the current decade; (4) the global financial, food, and economic crises broke out within the years 2007-2009; and (5) there has been an increased production of bio-fuel and all the consequences which have followed this phenomenon.

3.2 Econometric Techniques

This study undertakes econometrics techniques to examine the relationship between crude oil and each of the afore-mentioned commodity prices spanning 30 years using monthly prices. The goal behind the choice of these commodities is related to their usage in ethanol and bio-diesel production, thus, evaluating the minor hypothesis of the study which is whether or not the changes in crude oil prices play an important role in bio-fuel production.

This study adopts the free R software environment for statistical computing and graphics to maintain all tests on the time series under examination.

In order to test the hypothesis of whether or not there is a long run relationship between crude oil and food commodities, the study utilizes the methodology suggested by Engel and Granger *(Engel and Granger, 1987)*.

The variables used in this study are: crude oil price (PP), maize price (MP), soybean price (SBP), rice price (RP), wheat price (WP), barley price (BP), sorghum price (SP), linseed oil price (LOP), soybean oil price (SBOP), and palm oil price (POP).

The study adopts an econometrics model to denote the relationship between crude oil price and each of the food commodities under examination.

$$FC_iP_t = \beta_0 + \beta_1 PP_t + \varepsilon_t \quad (1)$$

where FC_iP_t is food commodity (i) price at time t, PP_t represents crude oil price at time t, and e_t is the error term.

3.2.1 Unit-root test

The Unit-root tests are used to determine whether the time series is stationary or non-stationary. A series is said to be weakly stationary if the mean and autocovariances of the series do not depend on time; any series whose mean and variance change over time is known as non-stationary *(Hatanaka, 2003)*. The need to test for the presence of unit root is to avoid the problem of spurious regression. If a variable contains a unit-root, then it is non-stationary, and unless it combines with other non-stationary series to form a stationary co-integration relationship, then regression involving the series can falsely imply the existence of a meaningful economic relationship.

In principle it is important to test the order of the integration of each variable in a model, to establish whether it is non-stationary and how many times the variable needs to be differenced to result in a stationary series. Furthermore, testing for stationarity for a single variable is very similar to testing whether a linear combination of variables co-integrates to form a stationary equilibrium relationship.

There are several ways of testing for the presence of a unit root. The emphasis here will be on using the Augmented Dickey Fuller approach (ADF) to test the null hypothesis that a series does contain a unit-root (non-stationary) against the alternative of stationarity.

This study applies the Augmented Dickey-Fuller (ADF) unit-root tests to decide the order of the integration of the series of the two variables. Note that the ADF is the wider version of the standard DF test used to overcome the problem of autocorrelation in the standard DF test; the DF test can be augmented by adding various lagged dependent variables. Akaike criteria (AIC) will be used to determine the optimal number of lags which is a necessary condition for further testing. According to the results of the ADF tests we should be able to determine whether time series are stationary or not. If the variables are difference stationary, it is appropriate to estimate the model by using the first difference in the variables. In this step we should already be able to reject the null hypothesis (existence of unit-root) in order to be able to conclude that the original time series are I(1). Note that if a series must be differenced *q* times before it becomes stationary, then it contains *q* unit-roots and is said to be integrated of order of *q* denoted as *I(q)*.

3.2.2 Testing Sequence for Unit Roots

After the optimal number of lags for all possible cases is determined, an augmented Dickey-Fuller (ADF) test is applied to all series under examination. First the encompassing ADF test equation is used:

$$\Delta Y_t = \beta_1 + \beta_2 t + \pi Y_{t-1} + \sum_{j=1}^{k} Y_j \, \Delta Y_{t-j} + u_t \quad (2)$$

Where Y_t is the series under examination (i) at time t, and u_t is the error term.

Now according to McLeod and Hipel (1978) we can rewrite the test regression (2) with three different combinations:

$$\Delta Y_t = \beta_1 + \beta_2 t + \pi Y_{t-1} + \sum_{j=1}^{k} Y_j \, \Delta Y_{t-j} + u_{1t} \quad (3)$$

$$\Delta Y_t = \beta_1 + \pi Y_{t-1} + \sum_{j=1}^{k} \gamma_j \, \Delta Y_{t-j} + u_{2t} \quad (4)$$

$$\Delta Y_t = \pi Y_{t-1} + \sum_{j=1}^{k} Y_j \, \Delta Y_{t-j} + u_{3t} \quad (5)$$

The testing starts by testing if $\pi = 0$ using *t* statistic critical values in Fuller (1976), not standard t distribution. If the test is rejected then we stop; otherwise the testing is continued for the presence of a trend by the *F* test φ_3 with $H_0: \beta_2 = \pi = 0$ if it is significant, then the standardized normal is used to test again for a unit root.

Otherwise it is estimated again, but in absence of trend, we repeat the same procedure and if the null hypothesis is rejected, we stop. If it is not, we go further with *F* statistics φ_1 for testing the presence of a constant and a unit root.

3.2.3 Estimating the long-run relationship
The second step in this methodology is to test for the existence or absence of co-integration. The main goal of a co-integration test is to examine if two or more series are linked to form an equilibrium relationship. The concept of co-integration means that the two price series cannot wander off in opposite directions for very long without coming back to a mean distance eventually.

3.2.4 Co-integration test
According to Engle and Granger (1987) if two series y_t and x_t are both *I(q)* in general any linear combination of two series will also be *I(q)*. If, however, there exists a vector β such that the disturbance term from the regression $(u_t = y_t - \beta x_t)$ is of a lower order of integration *I(q — b),* where $b > 0$, then Engle and Granger (1987) define y_t and x_t as being co-integrated of order *(d, b).* Thus, if v, and *x,* were both I (1) and $u_t \sim I(0)$, then the two series would be co-integrated of order CI (l. 1).
The purpose of the co-integration test is to determine whether a group of non-stationary series is co-integrated or not. For the purposes of this study, as mentioned above, the Engel-Granger two step method is utilized to investigate the existence or absence of co-integration. To that end the long run relationship (run regression) is estimated on equation 1 and the regression residuals are saved as regression residuals. Testing as to whether the residuals are stationary or not is then carried out again using a standardized ADF test, but here we must use the critical value found in MacKinnon's critical vales *(MacKinnon, 1991).* If we are able to reject the null hypothesis about the unit root, we can conclude that the variables are co-integrated of order CI(1,1).

3.2.5 Error Correction Model (ECM)
If we conclude co-integration in relation 1 we estimate the Error Correction Model (ECM). Basically, we estimate the following system of equations:

$$\Delta Y_t = \alpha_0 + \alpha_1 e_{t-1} + \sum_{i=1}^{m} \lambda_{12}(i)\,\Delta X_{t-1} \sum_{i=1}^{m} \lambda_{12}(i)\,\Delta X_{t-1} + \varepsilon^{x}{}_{t} \quad (6)$$

$$\Delta X_t = \alpha_0 + \alpha_1 e_{t-1} + \sum_{i=1}^{m} \lambda_{21}(i)\,\Delta Y_{t-i} + \sum_{i=1}^{m} \lambda_{22}(i)\,\Delta X_{t-1} + \varepsilon^{y}{}_{t} \quad (7)$$

The most important outcomes from the Error Correction Model (ECM) are the α_0 parameters which help us to conclude whether there is a one-or two-sided relationship between variables.

3.2.6 Causality test
The Granger test (1969) is to see how much of the current *y* can be explained by a past value of *x* and then to see whether adding lagged value can improve the explanation. *y* is said to be Granger-caused by *x* if *x* helps in the prediction of *y*, or equivalently if the coefficients on the lagged *x*'s are statistically significant. Note that two-way causation is frequently the case; *x* Granger causes *y* and *y* Granger causes *x.*
In this step the examining of the relationship by the traditional Granger causality test is simply to give an indicator of the relationship. Here it must be noted that the Granger causality test must be run on I(0) series, to test the hypothesis regarding whether ΔPP (Crude oil price) helps predict ΔFCP (Food commodity price). This is done by a simple F-test. The causality relationship can be evaluated by estimating the following:

$$\Delta X_t = \sum_{j=1}^{m} \alpha_{1j}\,\Delta X_{t-j} + \sum_{j=1}^{m} \beta_{1j}\,\Delta Y_{t-j} + \varepsilon_{1t} \quad (8)$$

and

$$\Delta Y_t = \sum_{j=1}^{m} \alpha_{2j}\,\Delta X_{t-j} + \sum_{j=1}^{m} \beta_{2j}\,\Delta Y_{t-j} + \varepsilon_{2t} \quad (9)$$

where X_t and Y_t are the prices of crude oil and food commodity respectively. The null hypothesis to be tested is that petroleum price does not Granger-cause food commodity price and food commodity price does not Granger-cause crude oil price i.e. $H_0{:}\beta_{1j}=0$, j=1,2,...m and $H_0{:}\alpha_{2j}=0$, j=1,2,...m.

If the null hypothesis is accepted, it means there is no causal relationship between the variables. In other words, two variables (crude oil and one of the food commodities in this study) are independent to each other. The rejection of one hypothesis indicates that there is one-directional causality between the variables. If both the hypotheses are rejected then it is an indication of bi-directional causality.

4. EMPIRICAL RESULTS

This study used time series data for monthly prices of crude oil and food commodities (cereals and vegetable oils to test the co-integration between crude oil and each one of the food commodities testes. As mentioned before, the period under examination extends from January 1980 through December 2009, with 3600 observations in total. Crude oil prices are expressed by United States Dollar (USD) price per barrel, while other food commodity prices are expressed by USD price per metric tonne.

In the course of this study we used the Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), and Hannan-Quinn Information Criterion (HQ) for selecting the optimal number of lags, but AIC is used to choose the bandwidth/lag length for the purposes of this study.

4.1 Augmented Dickey-Fuller test results

If the statistical characteristics -mean and variance- of the series are constant over time, then the series is said to be stationary process (no unit root), otherwise the series is described as being non-stationary i.e. the mean and variance are not constant over time (it has a unit root).Differencing techniques are normally used to transform a time series from non-stationary to stationary by subtracting each datum in a series from its predecessor.

We test the hypotheses that the series is (Greene, 2002):

H_0: Non-Stationary

H_1: Stationary

As Table 1 shows differencing of all price series under examination once is sufficient to achieve stationarity. It is clear that the null hypothesis (non-stationary) must be rejected for all series at the 5% level of significance. However, the null hypothesis can be rejected for all price series at better level. Thus all series are integrated of order 1 and the order of integration for each one is donated by I(1). Those results open the possibility of co-integration among crude oil price and each food price series under examination.

4.2 Co-integration analysis

We have identified that the price series of all commodities are integrated of the same order i.e. I(1). Now we will perform the Engle-Granger two step procedure for testing long-run co-integration. We test the bivariate relationship between oil and each of the food commodities in this study. As we addressed in the methodology the first step is to run regression on equation 1 and save the regression residual, then test whether the residuals are stationary using again the standard ADF test, but here we must use the critical value found in MacKinnon critical values *(MacKinnon, 1991).* If we are able to reject the null hypothesis about the unit root, i.e. the residuals are stationary, we can conclude that the variables are co-integrated of order CI(1,1).

The results are reported in Table 2. It is clear that we can reject the null hypothesis for all of them, thus the results indicate that there exists a long-run relationship between petroleum and food commodities under examination in this study at the 5% level of significance and better, except for rice at 10%. However, the value is at the 5% border.

Co-integration among the non-stationary prices of petroleum and the nine food commodities means that a linear combination of them is stationary and, consequently, prices tend to move towards this equilibrium relationship in the long-run.

4.3 The Error-Correction Model for the long-run relationship

In this section the results of the ECM are presented in order to check the model. We estimate equations 6 and 7.

The results of ECM are presented in Table 3. Here since we concluded from the previous test, i.e. the co-integration test that the two series are co-integrated, then there should be Granger causation at least in one direction. So at least one coefficient of the error term should enter equations 6 or 7 significantly and bear the correct sign, i.e. negative.

As we can notice from the results in Table 3, the error correction term for all variables holds the correct sign, i.e. negative in at least one direction, with quite a strong relationship. The results show a unidirectional relationship between crude oil price and the prices of maize and rice, and a bidirectional relationship between crude oil price and the prices of soybean, wheat, barley, sorghum, linseed oil, soybean oil, and palm oil.

According to the results the coefficients of the Error Correction Term which measure the speed of adjustment of maize, rice, soybean, wheat, barley, sorghum, linseed oil, soybean oil, and palm oil toward the equilibrium point at a speed of 1.96, 1.79, 0.75, 1.78, 0.35, 2.60, 1.11, 1.28, and 1.10 percent respectively. It is clear that the prices of sorghum and maize adjust at higher speed compared to the others while barley price adjusts at the lowest speed.

4.4 Traditional Granger Causality test

In this step we use the Granger Causality test to check the causal relationship between time series. The traditional Granger Causality test uses the F-test. To that end we run equations 8 and 9 and evaluate the causality by the standard F-test procedure. One must be aware here that using the Granger Causality test in our case is not sufficient *(Engle and Granger, 1987)* because all price series are I(1); however we use this test as an indicator for the direction of the relationship.

The compound hypotheses to be tested are:
H_{01}: Crude oil price does not Granger-cause food commodity price.
H_{11}: Crude oil price does Granger-cause food commodity price.
H_{02}: Food commodity price does not Granger-cause crude oil price.
H_{12}: Food commodity price does Granger-cause crude oil price.
Here we focus more on the relation from crude oil to food commodity because the opposite causality is less significant in this study; however all results are depicted in Table 4. The results show that Crude oil Granger-cause each of maize, rice, sorghum, linseed oil, and soybean oil, while, such causation is not clear for soybean, wheat, barley, and palm oil.

5. CONCLUSION AND POLICY IMPLICATIONS

This study addressed one of the uprising issues in economics. It examines the possible long-run relationship between the prices of crude oil and food commodities represented by maize, wheat, sorghum, soybean, barley, linseed oil, soybean oil, and palm oil. The period from January 1980 through December 2009, is used as the basis of this analysis. Econometric techniques (Unit root test, Co-integration, and Granger causality) are applied to investigate this relationship.

Based on the study findings we conclude that the empirical results of this study support the theoretical hypothesis that long-run relationship between crude oil and food commodities exists. Moreover, the results confirm that energy price, i.e. petroleum effects are growing in the agricultural sector, which is logical result since petroleum is considered one of the main inputs in agriculture and food production for activities such as planting, irrigation, harvesting, transportation, and marketing.

The findings also provide two important implications. Firstly, the information that is revealed should be very useful for short term trades in and between markets. Secondly, we can conclude that crude oil price changes might be a good predictor of food commodity price changes besides non-oil factors.

Nevertheless, the reader of this study should consider the limitation of this study before coming to any conclusions. Firstly this study did not take into account any structural breaks throughout the whole period. Secondly, the Engle-Granger two-stage estimation procedure was utilized for the purposes of this study; however some authors are uncomfortable with the two-stage approach since any mistake introduced in the first step is carried forward in the next step which is one of the weaknesses that limit the applicability of the Engle-Granger two-step procedure.

In recent years, it has become clear that all food commodities have increased and then fallen in tune with petroleum prices. Many authors *(Pinaranda and Micola,2009; Chakrabortty, 2008*) believe that the biofuel industry has developed as a reaction of high petroleum prices; however there does not seem to exist any study proof of that. In this study we were able to prove the co-integration between crude oil and biofuel crop prices, mainly for maize, sorghum, soybean, and soybean oil, which might be at least a signal of the linkage between the biofuel industry and petroleum prices. We believe that comparing the quantities and examining the co-movement between biofuel and petroleum econometrically would be the best proof of such a linkage between the biofuel industry and energy prices.

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TABELS:

Table 1. ADF tests for commodities under examination in the 1st difference

Commodity	Symbol	lag	*t*-value	*p*-value
Crude oil	DPP	9	-7.0664	9.18e-12
Maize	DMP	8	-6.760	6.04e-11
Rice	DRP	7	-8.3317	1.97e-15
Soybean	DSBP	8	-7.2357	3.12e-12
Wheat	DWP	8	-6.8755	2.98e-11
Barley	DBP	1	-12.3932	2e-16
Sorghum	DSP	8	-7.1836	4.34e-12
Linseed oil	DLOP	1	-11.002	2e-16
Soybean oil	DSBOP	5	-7.7984	7.5e-14
Palm oil	DPOP	4	-7.3196	1.75e-12

Notes: the 5% level of significance is used for the purposes of this study.

Table 2. Engle-Granger Co-integration test

Commodity	Test statistics	Result
Crude oil/Maize	-4.0507	Significant at 1%
Crude oil/Rice	-3.2531	Significant at 10%
Crude oil/Soybean	-3.7181	Significant at 5%
Crude oil/Wheat	-3.876	Significant at 5%
Crude oil/Barley	-3.4643	Significant at 5%
Crude oil/Sorghum	-4.3369	Significant at 1%
Crude oil/Linseed oil	-3.3856	Significant at 5%
Crude oil/Soybean oil	-3.5881	Significant at 5%
Crude oil/Palm oil	-3.5096	Significant at 5%

Notes: the critical values found in Mackinnon (1991) must now be used.
Critical values for this test are -3.93,-3.354, and -3.057, at the 1%, 5%, and 10% levels of significance respectively.

Table 3 Error Correction Model (ECM)

		DFC_iP								
		DMP	***DRP***	***DSBP***	***DWP***	***DBP***	***DSP***	***DLOP***	***DSBOP***	***DPOP***
DPP to DFC_iP	***Intercept***	0.001629	0.001593	0.001514	0.001585	0.001655	0.001575	0.001584	0.001493	0.001662
		(0.382)	(0.374)	(0.355)	(0.372)	(0.388)	(0.370)	(0.371)	(0.350)	(0.390)
	ECM	-0.019617	-0.017865	-0.007508	-0.017828	-0.003488	-0.025914	-0.011063	-0.012838	0.011054
		(-0.909)	(-1.148)	(-0.347)	(-0.790)	(-0.201)	(-1.106)	(-0.716)	(-0.683)	(0.798)
	F-Statistics	13.68	14.11	13.47	13.53	13.54	13.7	13.47	13.76	13.86
DFC_iP ***to DPP***	***Intercept***	0.000873	0.000598	0.000955	0.000482	0.001948	0.000767	0.000757	0.001038	-0.000664
		(0.299)	(0.192)	(0.322)	(0.175)	(0.497)	(0.243)	(0.207)	(0.327)	(-0.153)
	ECM	0.002136	0.004851	-0.001101	-0.003115	-0.012345	-0.002030	-0.009782	-0.000956	-0.0125033
		(0.312)	(0.692)	(-0.164)	(-0.437)	(-1.244)	(-0.263)	(-1.055)	(-0.131)	(-1.3580)
	F-Statistics	11.3	18.02	10.51	8.335	3.199	7.049	11.7	12.8	9.158

Notes: Numbers without parentheses are the coefficients
Numbers in parentheses are the *t*-values.

Table 4 Traditional Granger Causality Test

Commodity	Hypothesis	F-Statistics	*p*-value
Crude oil/Maize	H_{01} :PP does not Granger-cause MP	4.85482	0.0282
	H_{02} :MP does not Granger-cause PP	0.01823	0.8927
Crude oil/Rice	H_{01} :PP does not Granger -cause RP	17.1795	4.26e-05
	H_{02} :RP does not Granger-cause PP	1.94734	0.1638
Crude oil/Soybean	H_{01} :PP does not Granger-cause SBP	1.79237	0.1815
	H_{02} :SBP does not Granger-cause PP	0.19056	0.6627
Crude oil/Wheat	H_{01} :PP does not Granger-cause WP	1.40177	0.2372
	H_{02} :WP does not Granger-cause PP	0.22811	0.63322
Crude oil/Barley	H_{01} :PP does not Granger-cause BP	1.32955	0.24966
	H_{02} :BP does not Granger-cause PP	7.05843	0.0082
Crude oil/Sorghum	H_{01} :PP does not Granger-cause SP	7.52786	0.0064
	H_{02} :SP does not Granger-cause PP	0.01938	0.8894
Crude oil/Linseed oil	H_{01} :PP does not Granger-cause LOP	0.52443	0.469
	H_{02} :LOP does not Granger-cause PP	21.0073	6.35e-06
Crude oil/Soybean oil	H_{01} :PP does not Granger-cause SBOP	6.51339	0.0111
	H_{02} :SBOP does not Granger-cause PP	0.06784	0.7946
Crude oil/Palm oil	H_{01} :PP does not Granger-cause POP	3.26365	0.0717
	H_{02} :POP does not Granger-cause PP	0.04073	0.8402

Notes: the 5% level of significance is used for the purposes of this study.